

Sole Inventor

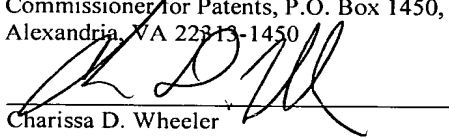
Docket No. 20067/OPP031479US

"EXPRESS MAIL" mailing label No.

EV 403728160 US

Date of Deposit: **December 30, 2003**

I hereby certify that this paper (or fee) is being deposited with the United States Postal Service "EXPRESS MAIL POST OFFICE TO ADDRESSEE" service under 37 CFR §1.10 on the date indicated above and is addressed to:
Commissioner for Patents, P.O. Box 1450,
Alexandria, VA 22313-1450


Charissa D. Wheeler

APPLICATION FOR UNITED STATES LETTERS PATENT

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

Be it known that I, Tae-Hee Park, a citizen of Republic of Korea, residing at 1028, Jung-dong, Wonmi-ku, Bucheon-city, Republic of Korea have invented a new and useful **Methods of Forming Metal Lines in Semiconductor Devices**, of which the following is a specification.

METHODS OF FORMING METAL LINES IN SEMICONDUCTOR DEVICES

TECHNICAL FIELD

[0001] The present disclosure relates to semiconductor devices and, more particularly, to methods of forming metal lines in semiconductor devices.

BACKGROUND

[0002] Metal lines used for electrical connection between elements in a semiconductor device are completed as an intended line pattern through a process including the steps of depositing aluminum mainly to form a metal layer, patterning a photoresist on the metal layer to form a photomask, and dry etching the metal layer in a region not protected by the photomask using an etching gas.

[0003] Currently, a process for dry etching the metal layer is performed using reactive gases of Cl series such as Cl_2 or BCl_3 . However, in the case of the reactive gases of Cl series, a problem arises in that the metal line is corroded unless the photomask is removed immediately after the metal layer is etched. This is because the aluminum metal layer is changed into a compound in the form of AlCl_x through a reaction with Cl_x and the compound causes the corrosion by reacting with moisture in the air when the compound is exposed in the air.

[0004] Therefore, conventionally, the photomask is generally removed under a vacuum state immediately after the metal layer is etched, and vapor and oxygen plasma ashing process has been used at a high temperature of 250 °C in order to remove chlorine composition absorbed on an entire surface of a wafer when the photomask is removed.

[0005] However, the above-described process has a problem in that the removal of the photomask is easily not performed. In addition, due to a problem of manufacture equipments, there is a problem in that the corrosion of the metal line occurs in the case that a process wafer has to be drawn out to the air immediately after the metal layer is etched.

[0006] As a result, it is not easy to form the metal line having the intended line pattern, and line defects of the semiconductor device are induced, which are major causes of malfunction of the semiconductor device.

[0007] To overcome these problems, techniques for etching an interlayer insulation film, a hard mask, etc., using etching gases of non-Cl series such as CF_4 , CHF_3 , C_3F_8 , C_2H_6 , and SF_6 , are disclosed in U.S. Patents 6,238,582 and 5,886,410.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Figs. 1A to 1E are views illustrating a metal line formation process of a semiconductor device according to one disclosed example.

DETAILED DESCRIPTION

[0009] First, as shown in Fig. 1A, a lower layer (not shown) formed by such as elements and lower lines is formed on a semiconductor substrate 1 and an interlayer insulation film (not shown) is formed on the lower layer for interlayer insulation between the lower layer and a metal line, which will be formed later. In addition, a lower adhesive layer 2, a metal layer 3, which is main material of the metal line, and an reflection layer 4 are formed in order on the interlayer insulation film.

[0010] The lower adhesive layer 2 and the anti-reflection layer 4 are films selectively deposited for enhancing an adhesive strength of the metal layer 3 to the semiconductor substrate 1 and preventing impurities from penetrating into the metal layer 3. The lower adhesive layer 2 and the anti-reflection layer 4 are made of Ti or TiN and are formed at a predetermined thickness by using a sputtering process or the like.

[0011] The metal layer 3 made of aluminum is formed at a thickness thicker than that of the lower adhesive layer 2, preferably, 4,000 to 6,000 Å, by using a sputtering process or the like.

[0012] Subsequently, after a photoresist is applied on the anti-reflection layer 4, an exposure and development process using an exposure mask (not shown) is performed for forming a predetermined pattern of photomask 5 to expose a portion to be etched.

[0013] Next, as shown in Fig. 1B, an initial etching process for dry etching the anti-reflection layer 4, which is not protected by the photomask 5, using C_3F_8 , BCl_3 and Ar as etching gases, is performed to expose a portion of a surface of the metal layer 3.

[0014] As conditions for performing the initial etching process, a pressure of 12mT, a source power of 1,200W and a bias power of 130W are used. In addition, C₃F₈ of 1 to 200sccm, BCl₃ of 1 to 100sccm, and Ar of 1 to 100sccm are used as process gases. In one example, C₃F₈ of 60sccm, BCl₃ of 50sccm, and Ar of 30sccm are used as process gases. In this initial etching process, an etching rate of Ti or TiN is 3,000 to 4,000 Å/min.

[0015] Subsequently, as shown in Fig. 1C, a main etching process using C₃F₈, NF₃, and N₂ as etching gases is performed. As a result of this process, the metal layer 3 in a region which is not protected by the photomask 5 is dry etched to expose a surface of the lower adhesive layer 2.

[0016] As conditions for performing the main etching process, a pressure of 12mT, a source power of 1,000W and a bias power of 100W are used. In addition, C₃F₈ of 1 to 200sccm, NF₃ of 1 to 100sccm, and N₂ of 1 to 100sccm are used as process gases. In one example, C₃F₈ of 90sccm, NF₃ of 50sccm, and N₂ of 10sccm are used as process gases. In this main etching process, an etching rate of aluminum is 6,000 to 7,000 Å/min.

[0017] In addition, as shown in Fig. 1D, an over-etching process using C₃F₈, NF₃, and N₂ as etching gases is performed. As a result of this process, the lower adhesive layer 2 in a region which is not protected by the photomask 5 is dry etched to remain the lower adhesive layer 2 only below the residual metal layer 3.

[0018] As conditions for performing the over-etching process, a pressure of 12mT, a source power of 1,000W and a bias power of 80W are used. In addition, C₃F₈ of 1 to 200sccm, NF₃ of 1 to 100sccm, and N₂ of 1 to 100sccm are used as process gases. Preferably, C₃F₈ of 80sccm, NF₃ of 50sccm, and N₂ of 5sccm are used as process gases. In this over-etching process, an etching rate of Ti or TiN is 4,000 to 5,000 Å/min.

[0019] As disclosed herein, when the main etching process and the over-etching process are performed, a C₃F₈ gas of carbon and fluorine series, which does not directly react with aluminum as material of the metal layer 3, may be used as a main etching gas and a small quantity of N₂ gas is added for polymer generation.

[0020] As the C_3F_8 gas and NF_3 gas do not directly react with aluminum, there is little fear of corrosion of the metal layer 3. In addition, as the C_3F_8 gas has an excellent characteristic in the etching rate respect over CF_4 gas used commonly, the former has a more advantage for metal line formation over the latter.

[0021] Finally, the photomask 5 residual on the anti-reflection layer 4 is removed to complete a metal line 6 as shown in Fig. 1E. In one example, as the C_3F_8 gas and NF_3 gas are used as main etching gases when the metal layer and the lower adhesive layer are dry etched, quality of the metal line 6 is not deteriorated even when the photomask 5 is not instantly removed after etching of the metal layer 3. Therefore, the problem of corrosion of the metal line can be overcome, and hence, malfunction of the semiconductor device can be prevented and semiconductor device yield can be greatly improved. In addition, because the photomask need not be instantly removed after the metal layer is etched, restriction on process conditions can be reduced.

[0022] As disclosed herein, example semiconductor device manufacturing methods are provided to forming a metal line in a semiconductor device that is capable of preventing line defects of a semiconductor device by preventing the metal line from being corroded, and eliminating a need of immediate removal of a photomask after etching of a metal layer. According to one example, a method includes forming a lower adhesive layer on a semiconductor substrate; forming a metal layer including aluminum on the lower adhesive layer; forming an anti-reflection layer on the metal layer; forming a photomask on the anti-reflection layer; performing an initial etching, a main etching and an over-etching for the anti-reflection layer, the metal layer and the lower adhesive layer, respectively, in a region which is not protected by the photomask, using C_3F_8 as a main etching gas; and removing the photomask residual on the anti-reflection layer.

[0023] In the foregoing example method, the metal layer may be formed by depositing aluminum at a thickness of 4,000 to 6000 Å. In another example, when the anti-reflection layer, the metal layer and the lower adhesive layer are etched, the etching is performed through the step of initial etching for etching the anti-reflection layer under the conditions of C_3F_8 of 1 to 200sccm, BCl_3 of 1 to 100sccm, and Ar of 1 to 100sccm, the main etching for etching the metal layer under the conditions of C_3F_8

of 1 to 200sccm, NF_3 of 1 to 100sccm, and N_2 of 1 to 100sccm, and the over-etching for etching the lower adhesive layer under the conditions of C_3F_8 of 1 to 200sccm, NF_3 of 1 to 100sccm, and N_2 of 1 to 100sccm.

[0024] Although certain example methods are disclosed herein, the scope of coverage of this patent is not limited thereto. On the contrary, this patent covers every apparatus, method and article of manufacture fairly falling within the scope of the appended claims either literally or under the doctrine of equivalents.